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(54) **Optical Fiber**

(57) In an optical fiber having a coating of plastic that is arranged over the optical waveguide, a thin polymer layer (4), of thickness1 μm to 125 μm, and low permeability to water vapor is arranged directly on a primary or secondary protective layer.

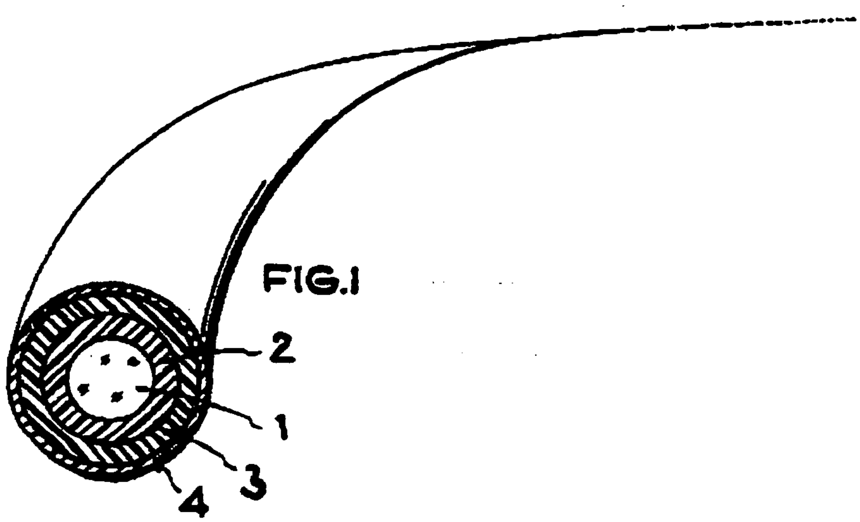

FIG.1

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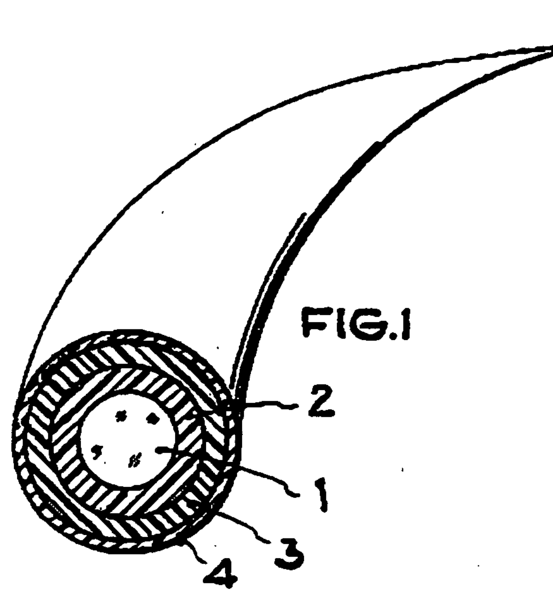

FIG.1

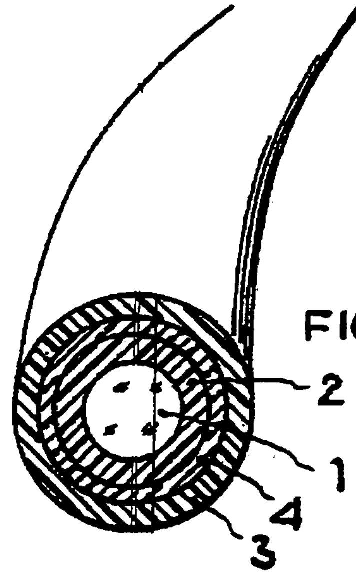

FIG.2

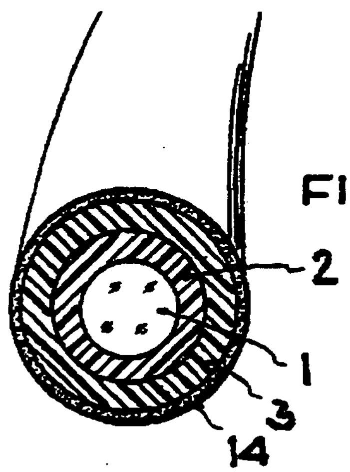

FIG.3

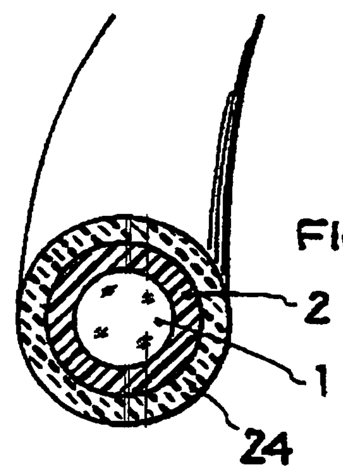

FIG.4

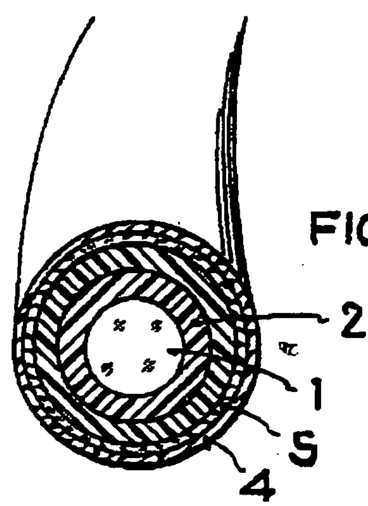

FIG.5

OPTICAL FIBER

The invention pertains to an optical fiber in accordance with the preamble of Claim 1. Optical fibers are generally comprised of a core and a jacket and a cylindrical form in which the lightwaves are guided. Since quartz glass is predominantly used for producing these fibers, a break in the fibers resulting from microcracks cannot be precluded. The cracks, which in the production of optical glass occur as a result of cooling, can grow by themselves through penetration of water. The actual glass fiber is generally coated with a lacquer-like material and a sheath of plastic in order to improve the mechanical strength.

However, glass fibers that are encased by sheaths in this way still exhibit various deficiencies in optical fiber cables. For example, breaks occur in the fiber cores under external compression or bending stresses.

Sheathed optical fibers exhibiting the above design are known. According to the method described in U.S. Patent Specification 39 80 390, prior to its contact with the environment or other solid objects a glass fiber spun from a melt is provided with a resin coating, to which a further coating made from a thermoplastic resin composition is applied in turn by means of melt extrusion. The first coating, called the primary coating, consists of a liquid resin that is applied to the surface of the fiber immediately after the fiber is drawn from the so-called extrusion onion. The coating serves to maintain the original strength of the glass material, while the subsequently applied coating made from a thermoplastic resin composition is intended to provide protection against mechanical stresses. This secondary protective layer is applied by extrusion. The protection of the fiber with such coatings consists primarily in the fact that mechanical injuries and microbends are largely prevented; however, this sheath usually does not provide adequate protection against moisture.

Water diffuses especially easily through plastic, and only highly specialized plastics have the property of exhibiting low permeability to water. In addition, both the primary and secondary coatings swell as a result of water absorption, and adhesion between coating and fiber is strongly degraded. As a result, problems arise due to the nonuniform loosening of the coating layers when the layers surrounding the glass fiber are removed.

The invention is based on the task of creating an optical fiber that is protected against the effect of water and can be removed easily in order to gain adequate fiber length for the splicing operation. The diffusion of water vapor should be effectively reduced so the optical fiber can have a long service life in terms of its mechanical and optical properties.

Areas of application of the invention are all information transmission lines with glass fibers on which [emphasis is placed] on particularly high-quality transmission, long service life and good removability when preparing the splice.

The invention is described in more detail below with the aid of a drawing. Figures 1–5 show fiber cross sections in schematic representation. In Figure 1, the primary coating has been applied to the glass fiber, the secondary coating extruded onto that, and finally, the water vapor barrier layer has been applied. Figure 2 shows an arrangement in which the vapor barrier has been arranged between the primary and secondary coatings. In Figure 3, the vapor barrier has an added function: it serves to distinguish the individual optical fibers through coding by means of color markings. Shown in Figure 4 is an option in which the vapor barrier additionally assumes the function of the secondary protective layer as a mechanically resistant layer. Figure 5 shows another variant in which the color layer that serves as coding is arranged under the vapor barrier.

To improve the surface protection of optical quartz glass fibers, an additional sealing or impregnation of the known surface protection is sought.

For example, the coatings polyacrylate layers, in particular, of polyurethane acrylate and/or polyepoxide acrylate and/or polyester acrylate layers as well as layers of their copolymers including their silane-, silyl-, siloxane-, halogen silane- or silazane-modified derivatives. These protective layers are preferably cured in UV. The water vapor barrier layer preferably consists of a thin layer of a polymer with very low water absorption or water vapor permeability.

These thin barrier layers can be applied from the gas phase, the liquid phase or from a solution, emulsion or suspension. First, an imperviously applied layer such as this seals off the pores that are present in the polymer material of the second or first coating layers. The barrier effect against water vapor and other vapors is based on the physical properties or the special chemical and structural design of the polymers used for the barrier layer. In particular,

the macromolecules of the polymer are largely nonpolar and/or contain halogen and are thus hydrophobic. The polymer structures are homogeneous, highly cross-linked, free from impurities, and thus especially impervious.

Examples of such barrier layer materials and their application are indicated below.

Example 1:

Process steps for the deposition of polyparaxylylene, polymonochloroparaxylylene, polydichloroparaxylylene or corresponding derivatives inside a closed facility are:

- Vaporization of the dimer (e.g., diparaxylylene) at approximately 175°C; 1 mbar
- Pyrolysis of the dimer at 680°C; 0.5 mbar
- Deposition at 35°C; 0.1 mbar.

Depending on the deposition time, a pore-free and very dense layer can be obtained, 1 to more than 10 μm thick.

The water absorption of this layer after 24 hours is 0.06% (polyparaxylylene) or even as little as 0.01% (polymonochloroparaxylylene) in comparison to 3% with polyurethane acrylate. The water vapor permeation at 37°C and 90% relative humidity and increasing chlorine substitution of the polymer is 1.6–0.5–0.25 relative units, and considered in absolute terms, it is two to three decimal powers lower than with polyacrylate layers.

Example 2:

The magnetron sputtering method or plasma polymerization by means of, for example, DC, RF or microwave plasma polymerization (the latter, for example, at 2450 MHz; 2.5 kW generator, Ar pressure 1 to 40 Pa) is used in the deposition of polymer layers of hydrocarbons, hydrocarbons containing fluorine or hydrocarbons containing silicon. The following monomer groups are used when doing that:

- Acetylene, ethylene, methane or higher alkines, alkenes and alkanes, benzene and its homologs
- Tetrafluoroethylene, tetrafluoromethane, chlorodifluoromethane, hexafluoropropene or similar hydrogen halides
- Hexamethyldisiloxane, hexamethyldisilazane, trimethylchlorosilane or similar organic silicon compounds.

Depending on the process conditions (substrate temperature, monomer flow rate, carrier gas, pressure, bias voltage, microwave power and frequency), it is possible to obtain soft to hard layers with a chemical composition that can vary correspondingly from polyhydrocarbons to -hydrocarbon layers. The desired composition and property can thus be adjusted, e.g., hardness up to 5000 HV. This criterion is also a measure of, among other things, the diffusion inhibition of such layers. The layer thickness can be 0.5 μm or more.

Example 3:

Used in the deposition of polyethylene, polypropylene or polymethylpentene from the liquid phase is a five percent solution (or suspension) of, for example, superfine powder (< 35 μm grain size) obtained through cold grinding and screening, in decaline (decahydronaphthalene) at 100°C. The fiber, which has received at least one surface protection by means of a primary coating, is immersed in the liquid, and layers approximately 1–5 μm thick are obtained after the majority of the solvent is evaporated and the polymer portion is fused or sintered at 150°-200°C. These layers have – as is known from polyethylene, for example – low water vapor permeability. The hardness and abrasion resistance of the layer can be adjusted through appropriate selecting and mixing of several constituents (high-pressure, low-pressure, linear polyethylene) and the solvent content remaining in the layer. The higher the latter is, the softer and more gel-like the sealing layers are.

Example 4:

The optical fiber that has been provided with the primary coating and possibly with a secondary coating as well is sealed by means of immersion (or wetting). To do this, the fiber is immersed in the liquid monomer or oligomer of a thermally curable or UV reactive substance, e.g., an acrylate, with subsequent thermal treatment and/or UV irradiation. As a result, the coating applied to the fiber swells more or less deeply depending on the length of the immersion or wetting time. As a result, monomersor low-molecular oligomer molecules can be diffused into the polymer structure of the fiber coating. Inside the polymer structure, these oligomer molecules react with the still-remaining

function groups of the polymer and with each other so that the three-dimensional cross-linking of the polymer is strengthened by additional bonds. The polymerization initiators that are still present within the polymer structure act in supporting fashion through formation of radicals during the thermal exposure or, in particular, during the UV exposure. The non-cross-linking monomer or oligomer portions are volatilized by the thermal treatment so that the swelling of the fiber coating abates and in sum, a denser coating microstructure is obtained, particularly in the region near the surface.

For example, monofunctional acrylates, such as 2-ethylhexyl acrylate or 2-hydroxyethyl acrylate, difunctional acrylates such as 1,4-butanediol diacrylate or 1,6-hexanediol diacrylate, trifunctional acrylates such as, trimethylolpropane triacrylate or pentaerythritol triacrylate, or in particular, mixtures of such monomers and/or their oligomers, can be used as the monomers. Additional application examples are N-vinylpyrrolidon or other thermally IR or UV polymerized substances.

Claims

1. Optical fiber with a coating of plastic that is arranged over the lightwave conductor, **characterized in that** a thin polymer layer of 1 μm to 125 μm thickness and low water vapor permeability is arranged directly on a primary or secondary protective layer.
2. Optical fiber according to Claim 1, characterized in that the water vapor barrier layer seals the surface protective layer of the optical fiber in that it closes off the pores in the surface protective layer.
3. Optical fiber according to Claim 1 or 2, characterized in that the water vapor barrier layer (4) is hydrophobic.
4. Optical fiber according to one of the Claims 1 through 3, characterized in that the water vapor barrier layer (4) exhibits a low water vapor diffusion coefficient and a low oxygen diffusion coefficient.
5. Optical fiber according to one of the Claims 1 through 4, characterized in that the water vapor barrier layer (4) is preferably 5–20 μm thick.
6. Optical fiber according to one of the Claims 1 through 5, characterized in that the water vapor barrier layer is 20–50 μm thick.
7. Optical fiber according to one of the Claims 1 through 6, characterized in that the water vapor barrier layer is used for color marking the optical fiber.
8. Optical fiber according to one of the Claims 1 through 7, characterized in that the water vapor barrier layer (4) is made of polyvinyl alcohol.
9. Optical fiber according to one of the Claims 1 through 8, characterized in that the water vapor barrier layer (4) is made of polyxylylene.
10. Optical fiber according to one of the Claims 1 through 9, characterized in that polyparaxylylene, polymonochloroparaxylylene, polydichloroparaxylylene or corresponding mixtures of these polymers are used as the water vapor barrier layer.
11. Optical fiber according to one of the Claims 1 through 7, characterized in that acrylate is used as the water vapor barrier layer.
12. Optical fiber according to one of the Claims 1 through 7, characterized in that a plastic made of polyvinylidene chloride (PVDC), or polytrifluoro-ethylene [sic] (PCTFE), or polytetrafluoroethylene (PTFE), or polyvinylidene fluoride (PVDF), or polyvinylfluoride (PVF) is used.
13. Method for producing an optical fiber according to one of the Claims 1 through 12, characterized in that the diffusion barrier layer is produced from the gas phase by means of polymerization, and that curing is performed by means of high-energy rays.